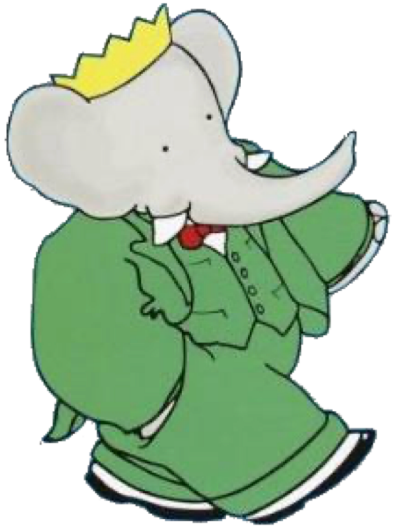
Recent *BaBar* results on measurement of exclusive hadronic cross sections



Evgeny Solodov for BaBar Collaboration

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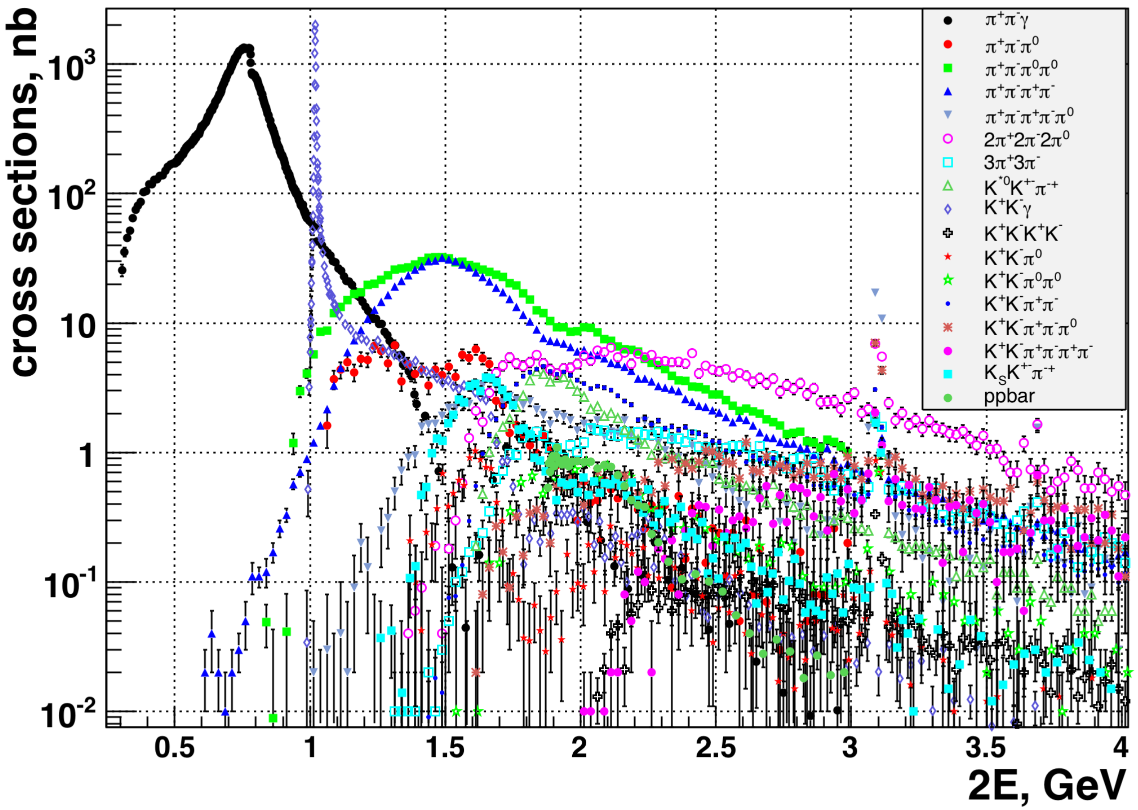
June 29, 2021

Outline

- Recently completed (published) analyses
  - $e^+e^- \to 2(\pi^+\pi^-)\pi^0\pi^0\pi^0(\eta)$ – reported at ICHEP2020, published Phys. Rev. D 103 (2021) 092001
  - $e^+e^- \to \pi^+\pi^-\pi^0\pi^0\pi^0\pi^0(\eta)$ – reported at ICHEP2020, preliminary, at last stage review - soon
- Analyses in progress
  - $e^+e^- \to \pi^+\pi^-\pi^0$ new analysis, x5 more data
  - $e^+e^- \to \pi^+\pi^-$ new analysis, x7 more data, new method
  - $e^+e^- \to 2K3\pi$ new analysis
- Conclusion

BaBar low energy hadron cross sections

- BaBar has developed the ISR tools and is continuing an intensive program for low energy e+e- cross section study for more than 15 years.
- At the moment BaBar has presented most complete set of exclusive cross sections at low c.m. energies
- Uncertainties vary from 0.5-2% for 2h, 3-5% for 3-4hadrons and 7-15% for multi-hadron states.
- BaBar data have very important role in HVP calculations, somewhere dominate.
- BaBar still plans to improve already published data and plans to present new measurements.



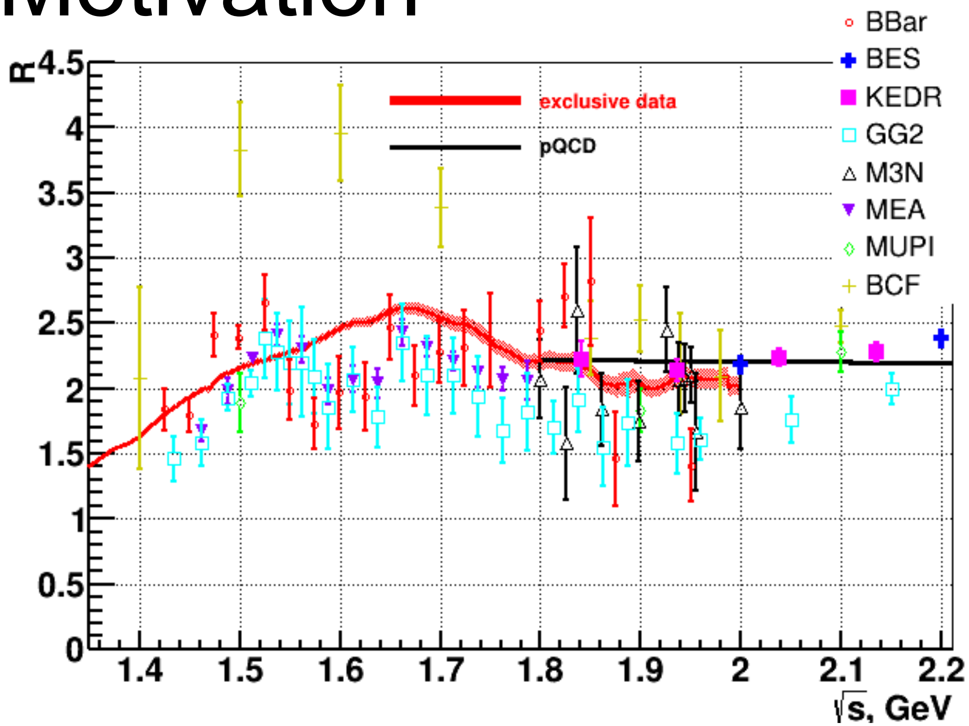
BaBar ISR measurements (March 2021)

$2(\pi^+\pi^-)\pi^0\pi^0\pi^0$, $2(\pi^+\pi^-)\pi^0\pi^0\eta$		Phys. Rev. D 103 (2021) 092001
$\pi^+\pi^-\pi^0\pi^0\pi^0$, $\pi^+\pi^-\pi^0\pi^0\eta$		Phys. Rev. D 98 (2018) 112015
$\pi^+\pi^-\pi^0\pi^0$		Phys. Rev. D 96 (2017) 092009
$\pi^+\pi^-\eta$		Phys. Rev. D 97 (2018) 052007
$K^0_S K^0_L \pi^0$, $K^0_S K^0_L \eta$, and $K^0_S K^0_L \pi^0\pi^0$		Phys. Rev. D 95 (2017) 052001
$K^0_S K^+\pi^-\pi^0$, $K^0_S K^+\pi^-\eta$		Phys. Rev. D 95 (2017) 092005
K^+K^-	γ undet.	Phys. Rev. D 92 (2015) 072008
$K^0_S K^0_L$, $K^0_S K^0_L \pi^+\pi^-$, $K^0_S K^0_S \pi^+\pi^-$, $K^0_S K^0_S K^+K^-$		Phys. Rev. D 89 (2014) 092002
$\bar{p}p$	γ undet.	Phys. Rev. D 88 (2013) 072009
$\bar{p}p$		Phys. Rev. D 87 (2013) 092005
K^+K^-	NLO	Phys. Rev. D 88 (2013) 032013
$\pi^+\pi^-$	NLO	Phys. Rev. Lett. 103 (2009) 231801
$2(\pi^+\pi^-)$		Phys. Rev. D 85 (2012) 112009
$K^+K^-\pi^+\pi^-$, $K^+K^-\pi^0\pi^0$, $K^+K^-K^+K^-$		Phys. Rev. D 86 (2012) 012008
$K^+K^-\eta$, $K^+K^-\pi^0$, $K^0K^\pm\pi^\mp$		Phys. Rev. D 77 (2008) 092002
$2(\pi^+\pi^-)\pi^0$, $2(\pi^+\pi^-)\eta$, $K^+K^-\pi^+\pi^-\pi^0$, $K^+K^-\pi^+\pi^-\eta$		Phys. Rev. D 76 (2007) 092005
$\Lambda\bar{\Lambda}$, $\Lambda\Sigma^0$, $\Sigma^0\Sigma^0$		Phys. Rev. D 76 (2007) 092006
$3(\pi^+\pi^-)$, $2(\pi^+\pi^-\pi^0)$, $K^+K^-2(\pi^+\pi^-)$		Phys. Rev. D 73 (2006) 052003
$\pi^+\pi^-\pi^0$		Phys. Rev. D 70 (2004) 072004

Magenta: First measurements, Green: 454 - 469 fb^{-1}, Cyan: 232 fb^{-1}, Blue: 89 fb^{-1}

Superseded results omitted

Motivation



Because of large, highly granulated calorimeter BaBar has advantage for study of the multi-photon reactions over detectors at VEPP2000 (SND and CMD-3) even effective integrated luminosity is already lower.

Currently, the sum of exclusive cross sections near 2.0 GeV shows a systematic deviation from the QCD predictions.

BABAR, SND and CMD-3 measurements of previously unmeasured processes, e.g. $e^+e^- \to \pi^+\pi^-\pi^0\pi^0\pi^0\pi^0$, $\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\pi^0$, $K_SK^+\pi^-\pi^0\pi^0$, $K^-K^+\pi^0\pi^0\pi^0$, … may help to understand if this discrepancy is real.

$e^+e^- \to 2(\pi^+\pi^-)\pi^0\pi^0\pi^0(\eta)$ and $\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0(\eta)$ at c.m. energies from threshold to 4.5 GeV using ISR

Analyses are based on tools developed for the $e^+e^- \to \pi^+\pi^-\pi^0\pi^0\pi^0$ - published in **Phys.Rev. D98 (2018) no.11, 112015** - two charged or one π^0 are added to the procedure

- 469 fb^{-1} of BaBar data
- ~200k MC simulation for $e^+e^- \to 2\pi 2\pi^0 \eta\gamma$ (PS, $\omega\pi^0\eta\gamma$)
- ~500k MC simulation for $e^+e^- \to \omega\eta\gamma$
- MC includes all radiative processes
- Background processes (from MC):

$e^+e^- \to \tau^+\tau^-$

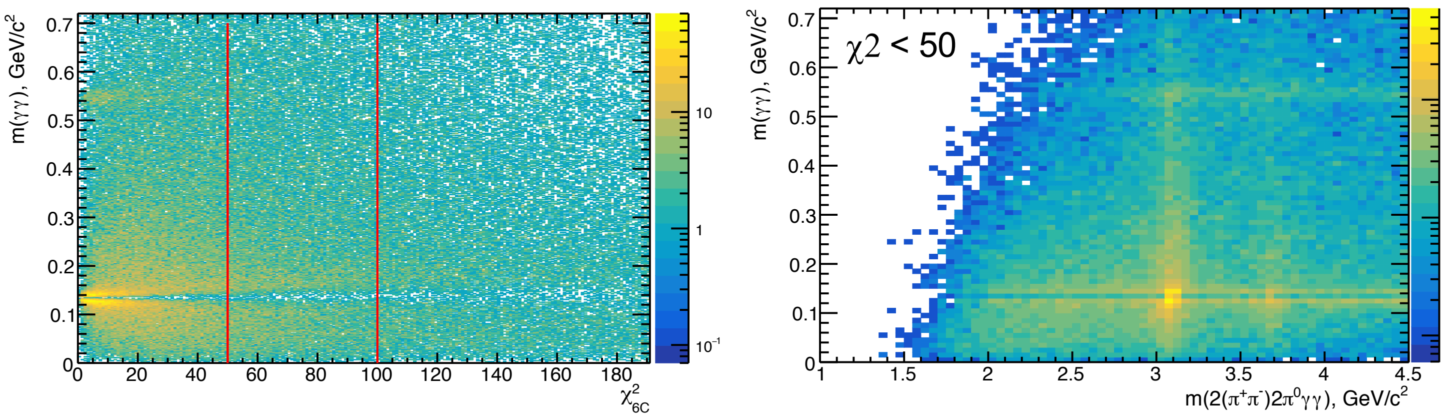
$e^+e^- \to qq$ (q = u,d,s,c) - major background is from $e^+e^- \to 4\pi 4\pi^0, 2\pi 5\pi^0$

$e^+e^- \to 3\pi\gamma, 4\pi\gamma, 5\pi\gamma, 6\pi\gamma, 4\pi 2\pi^0\gamma(!)$ – $\omega\eta$ final state

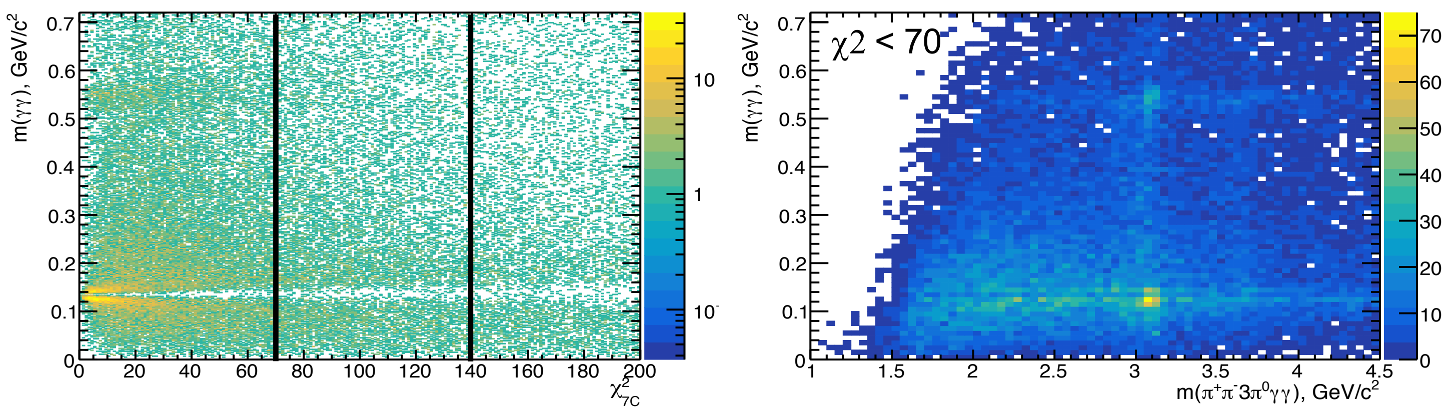
Analysis procedure (without details):

- Select events with 4(2) charged tracks and 7(9) or more photons (up to 25 sometimes)
- Take most energetic photon as ISR
- For each independent set of 6(8) photons test all combinations of 3(4) $\gamma\gamma$ pairs with ±35 MeV windows around π^0 mass.
- Perform 6C (7C) fit in $4\pi 2\pi^0\gamma\gamma\gamma_{ISR}$ ($2\pi 3\pi^0\gamma\gamma\gamma_{ISR}$) hypothesis with π^0 mass constrain for two (three) best pairs, NO constrain on mass for 3rd (4th) $\gamma\gamma$ pair.
- Look for best χ^2, trying all pairs to be 3rd or 4th

Experimental distributions for 3rd (4th) $\gamma\gamma$ pair

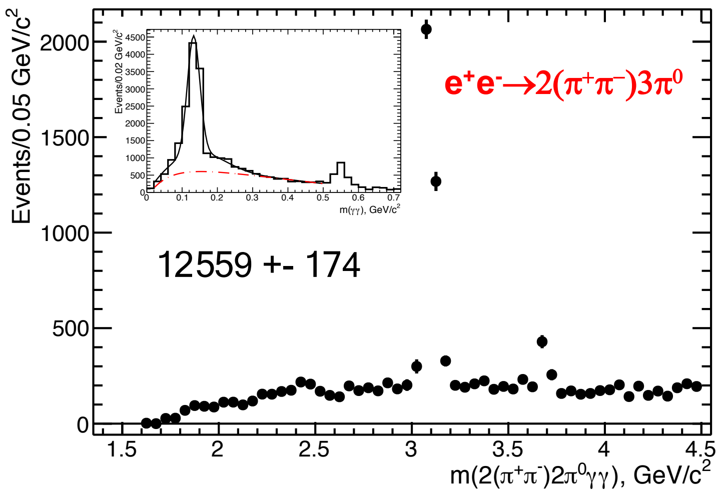


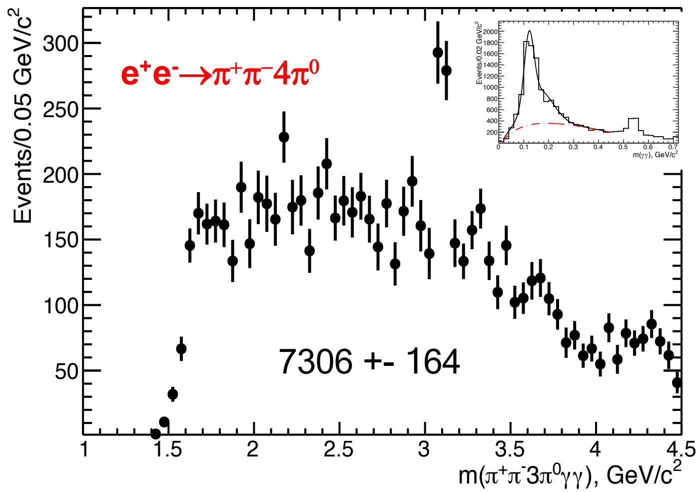
$e^+e^- \to 2(\pi^+\pi^-)\pi^0\pi^0\pi^0(\eta)$



$e^+e^- \to \pi^+\pi^-\pi^0\pi^0\pi^0\pi^0(\eta)$

Fit of π^0 signal in data

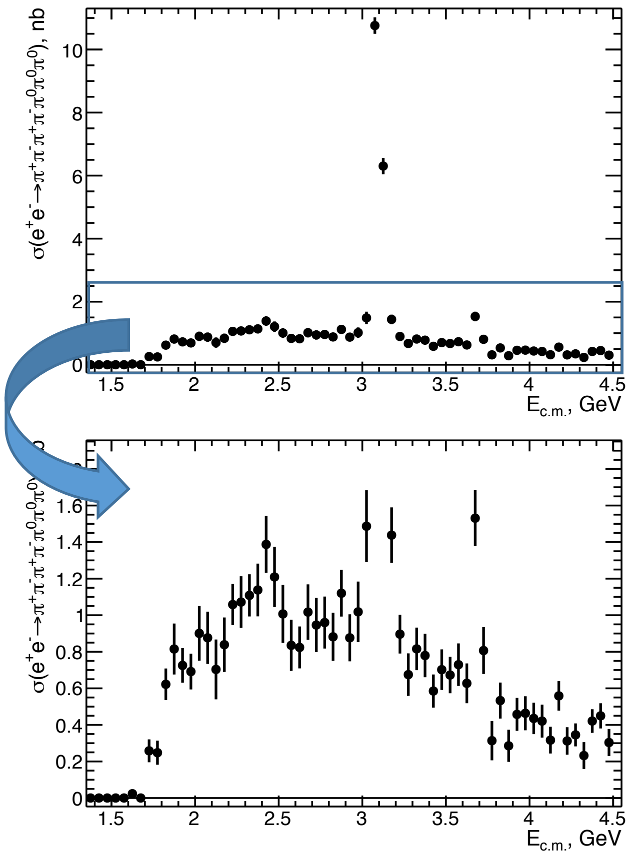




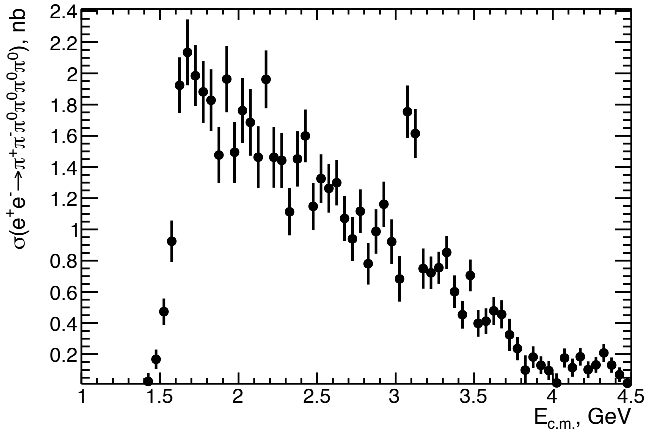
Fit in every 0.05 GeV, using π^0 shape from simulation after background subtraction from control region. Remaining background - a polynomial function.

Cross sections

$e^+e^- \rightarrow 2(\pi^+\pi^-)\pi^0\pi^0\pi^0$



$e^+e^- \rightarrow \pi^+\pi^-\pi^0\pi^0\pi^0\pi^0$



No other measurements

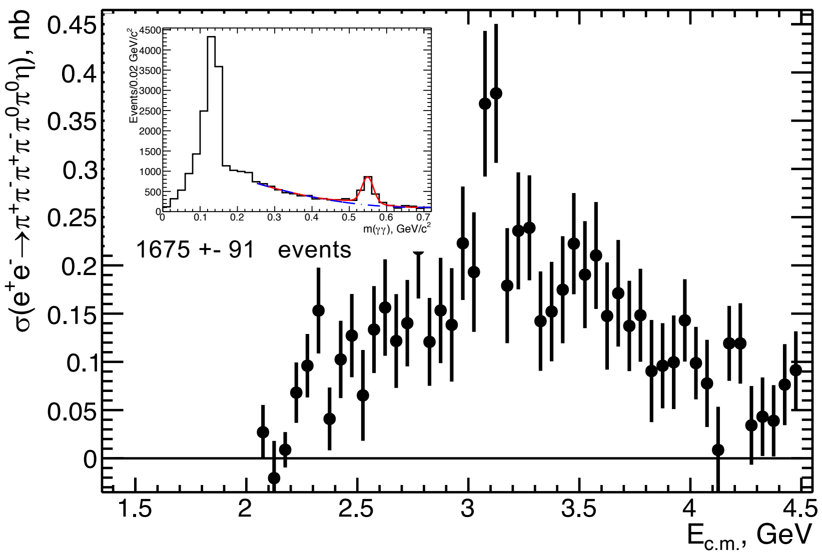
Corrections and systematic uncertainties:

Fit procedure	--	5-7%
Tracking efficiency	+4(2)	2%(1%)
Luminosity	--	1%
Efficiency(model + fits)	--	5%
χ^2 cut uncertainty	--	3%
π^0 efficiency	+9(12)	3%(4%)
Radiative corr.	--	1%
ISR photon eff.	+1.5	0.5%
Total	+14.5(15.5)	~10%

Similar fit of η signal

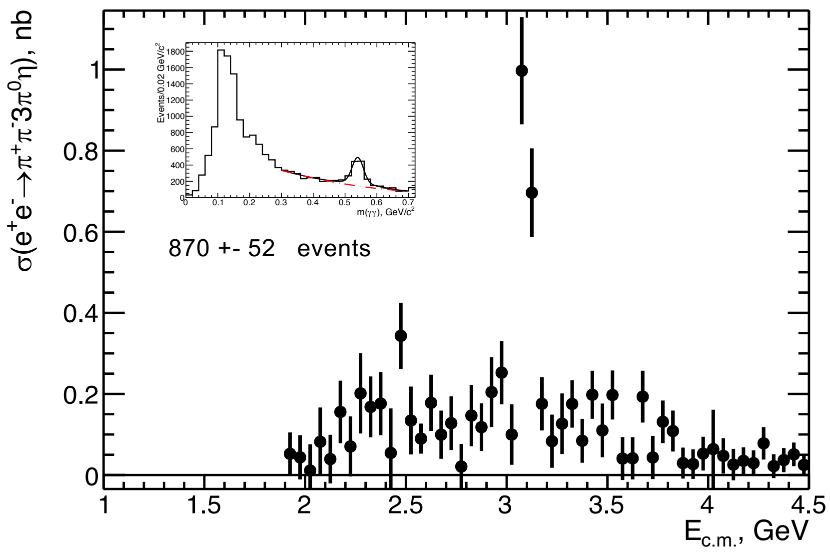
Using η shape as double Gaussian and flat background shape, we fit for every 0.05 GeV/c^2

$e^+e^- \to 2(\pi^+\pi^-)\pi^0\pi^0\eta$



Well above 2 GeV, events are normalized by efficiency and lumi for the cross section.

$e^+e^- \to \pi^+\pi^-\pi^0\pi^0\pi^0\eta$

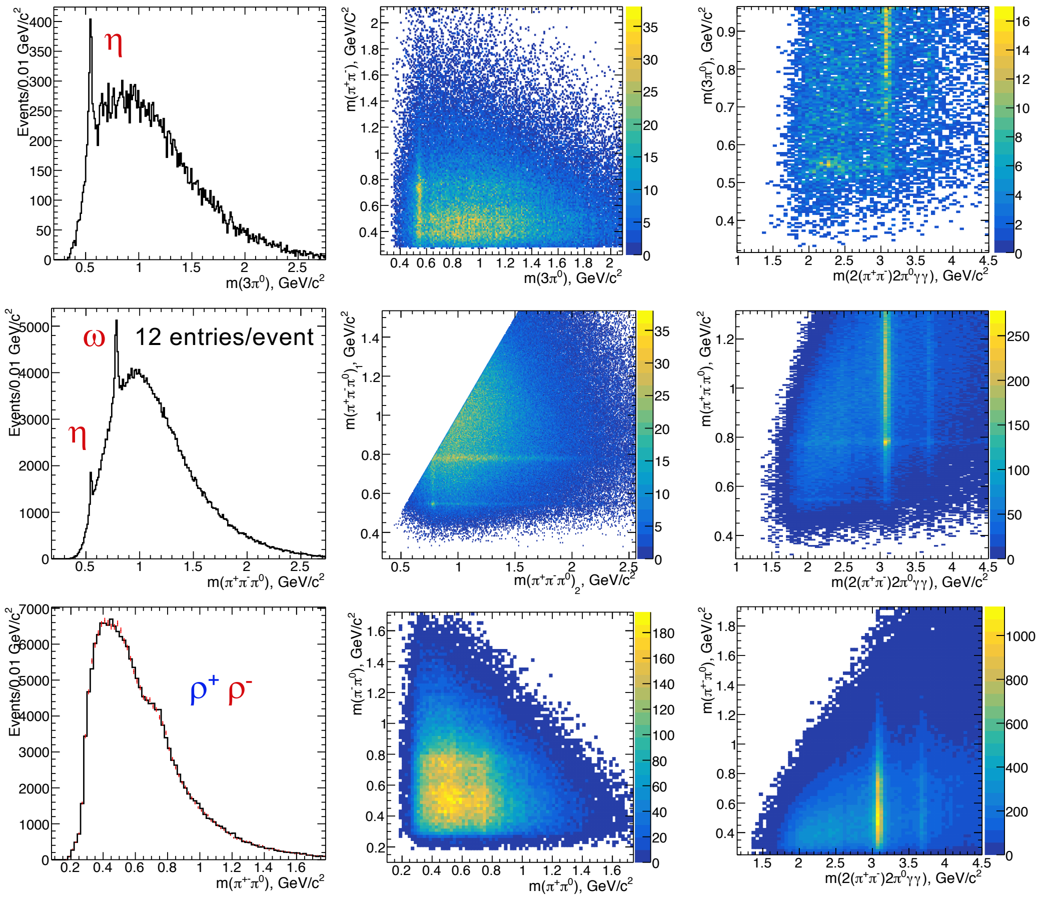


BR(η –> γγ) is taken into account

Well above 2 GeV – J/psi BR is large…

No other measurements

What we have inside of 7π? $m(\gamma\gamma)<0.3$ GeV/c^2



Dominates by

$e^+e^- \to \eta\pi^+\pi^-\rho^0\,(a_1\pi\eta)$

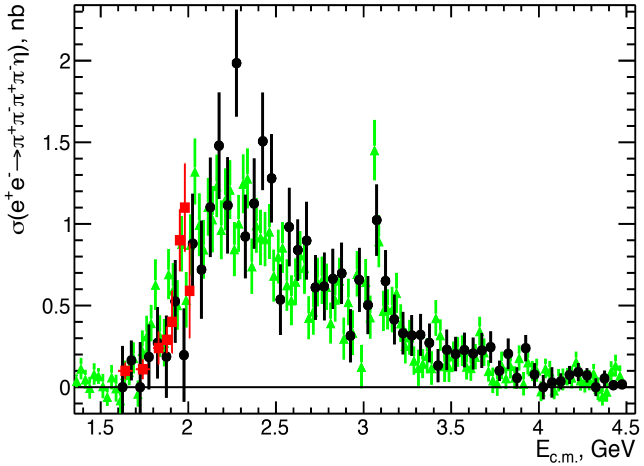
$e^+e^- \to \omega(\eta)\pi^+\pi^-\pi^0\pi^0$, $\omega\eta\pi^0$

$e^+e^- \to \rho^{\pm}5\pi$, $(\rho^+\rho^-3\pi)$?

J/ψ production dominates

Cross sections for intermediate states in $4\pi 3\pi^0$

$e^+e^- \to \eta\pi^+\pi^-\pi^+\pi^-$

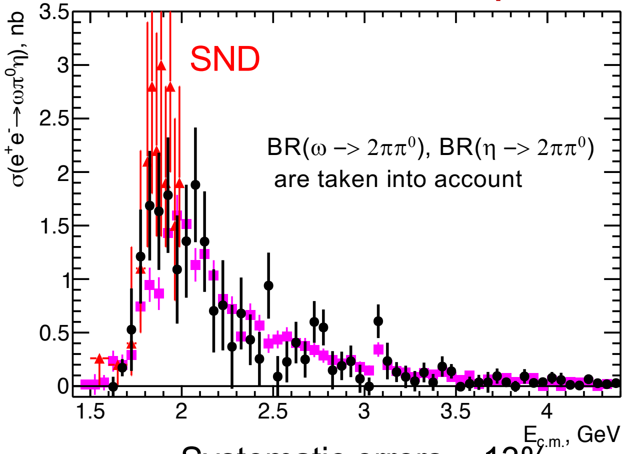


BR($\eta \to 3\pi^0$) is taken into account

BaBar $\eta \to \gamma\gamma$ (**Phys.Rev. D76 (2007) 092005**)

CMD-3 $\eta \to \pi^+\pi^-\pi^0$ **Phys.Lett. B792 (2019) 419-423**

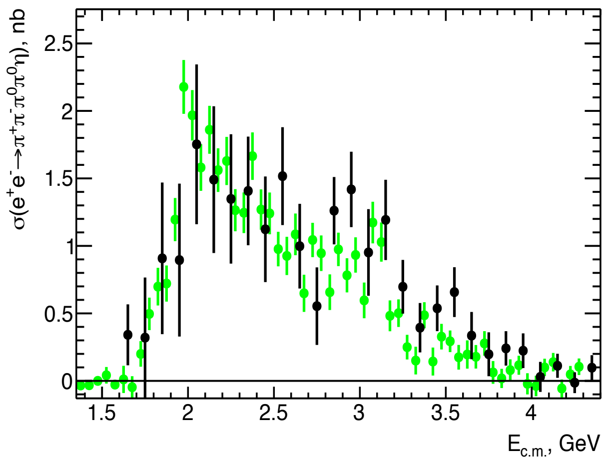
$e^+e^- \to \omega\pi^0\eta$



Systematic errors ~ 13%

We are in agreement with the BaBar data for the $e^+e^- \to \omega\pi^0\eta(\eta \to \gamma\gamma)$ reaction **Phys.Rev. D98 (2018) no.11, 112015**, and still are lower than SND measurement.

$e^+e^- \to \eta\pi^+\pi^-\pi^0\pi^0$

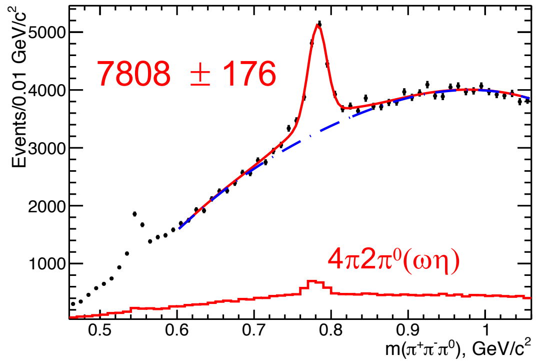


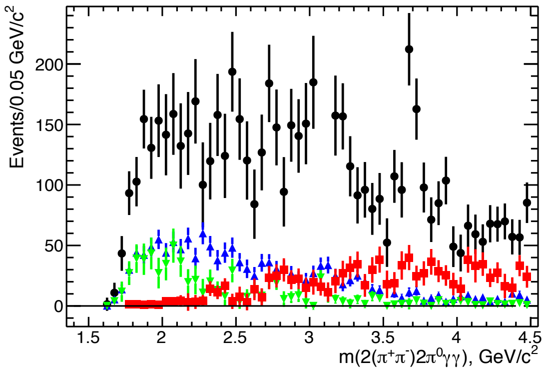
Cross section is shown for the 0.1 GeV intervals.

Reasonable agreement with our recent result for $\eta \to \gamma\gamma$ mode **Phys.Rev. D98 (2018) no.11, 112015**

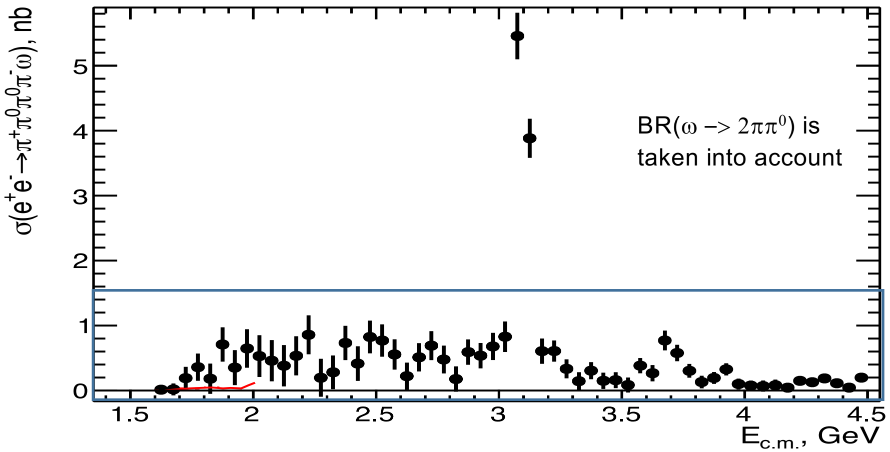
Good agreement with previously measured cross sections in different decay modes of ω, η

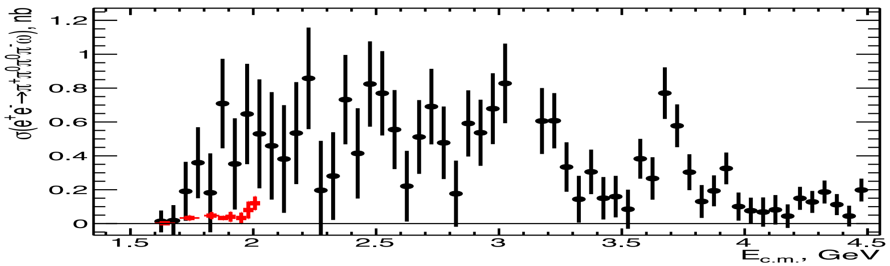
Cross section for $e^+e^- \to \omega\, \pi^+\pi^-\pi^0\pi^0$





We subtract peaking background contribution from $4\pi 2\pi^0$, events from $\omega\pi^0\eta$ reaction, and uds



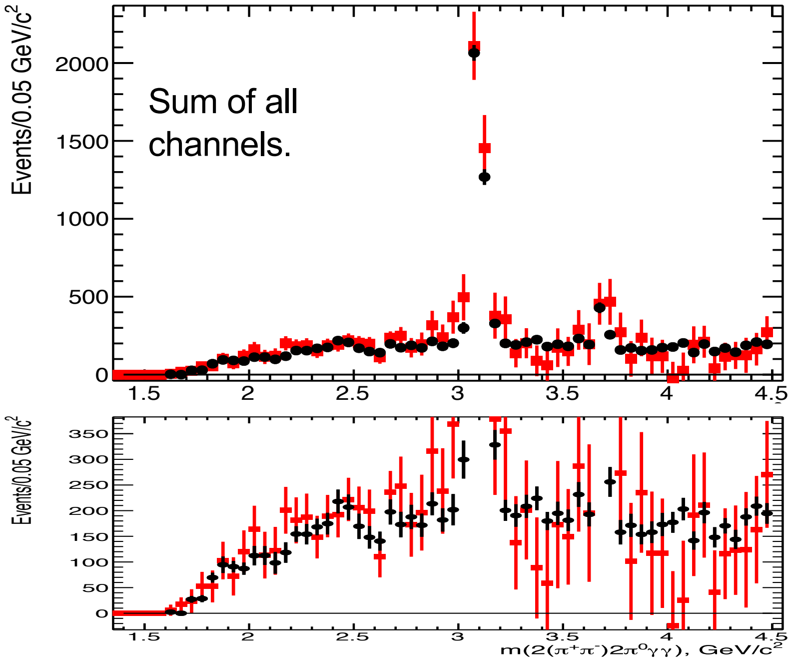


No other measurements

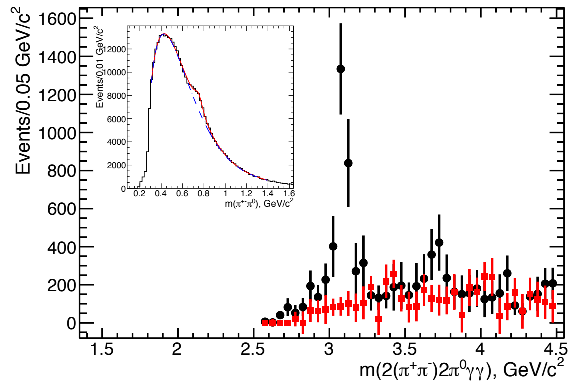
CMD-3 results are shown for the $e^+e^- \to \omega\, \pi^+\pi^-\, \pi^+\pi^-$ reaction
Phys.Lett. B792 (2019) 419-423

Contribution from different channels

$e^+e^- \to \pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\pi^0$



$\rho\pi\pi^+\pi^-2\pi^0$

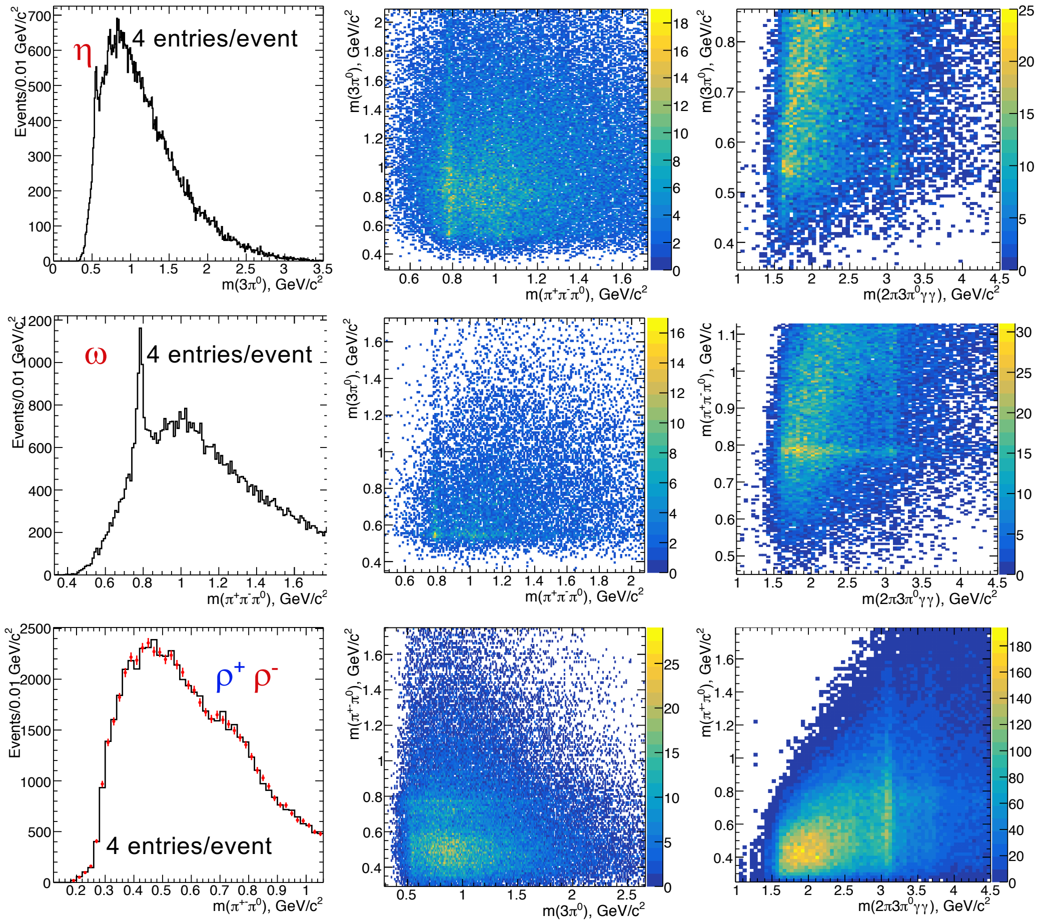


ρ signal is scaled by
(2014+415)/2844 = 0.85
to account for $\rho^+\rho^-$

The observed $4\pi3\pi^0$ events are covered by the $\omega\pi^0\eta$, $\omega\pi^+\pi^-2\pi^0$, $\eta\pi^+\pi^-2\pi^0$, $\eta2(\pi^+\pi^-)$ for < 3 GeV, and includes $\rho\pi\pi^+\pi^-2\pi^0$ channels for >2.5-3 GeV

What we have inside of 6π?

$|m(\gamma\gamma)-m\pi^0|<0.1$ GeV/c^2



Dominates by

$e^+e^- \to \eta\pi^+\pi^-\pi^0$, $\omega\eta$

$e^+e^- \to \omega(\phi)\pi^0\pi^0\pi^0$,

$\omega(\phi)\eta$

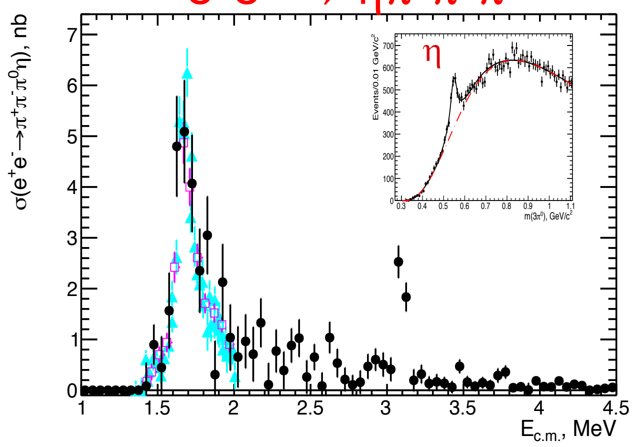
$e^+e^- \to \rho^\pm 4\pi$,

$\rho^\pm\pi^\mp\eta$? $\rho^\pm\rho^\mp 2\pi^0$?

J/ψ production dominates

Cross sections for intermediate states in $2\pi4\pi^0$

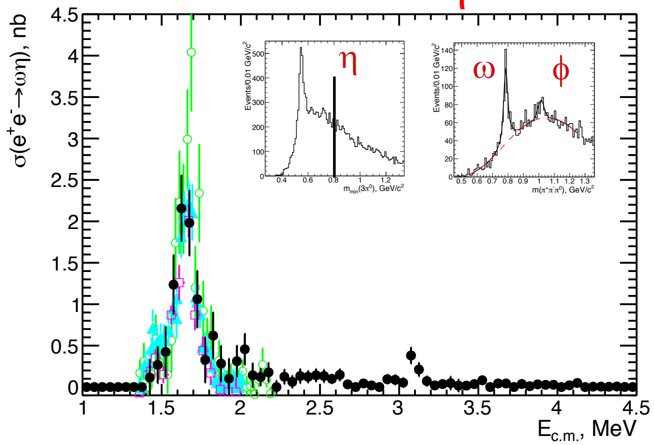
$e^+e^- \to \eta\pi^+\pi^-\pi^0$



BR($\eta \to 3\pi^0$) is taken into account

CMD-3 (**Phys.Lett. B773 (2017) 150-158**)
SND (**Phys.Rev. D99 (2019) no.11, 112004**)
have published this cross section for
$\eta \to \gamma\gamma$ mode up to 2.0 GeV

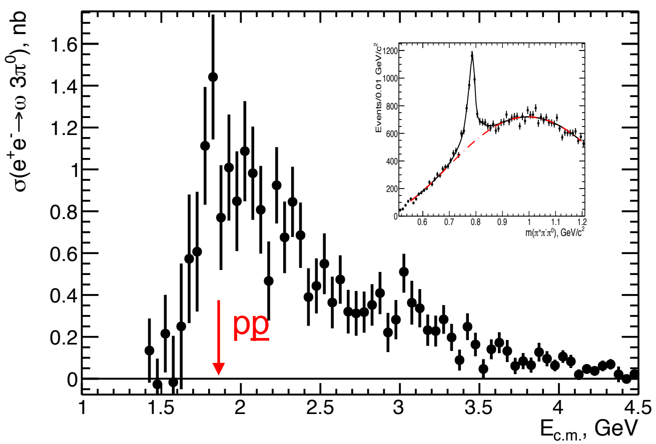
$e^+e^- \to \omega\eta$



BR($\omega \to 2\pi\pi^0$), BR($\eta \to 3\pi^0$)
are taken into account

We are lower than the BaBar data for the $e^+e^- \to \omega\eta(\eta \to 2\pi\pi^0)$ reaction, and in agreement with SND and CMD-3 measurements.

$e^+e^- \to \omega\pi^0\pi^0\pi^0$

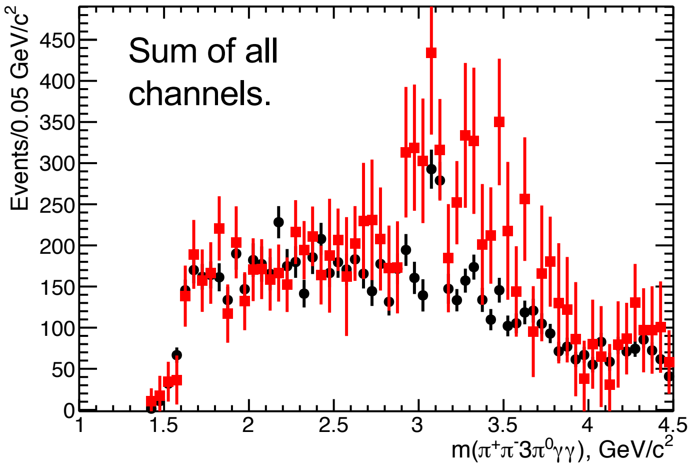


BR($\omega \to 2\pi\pi^0$) is taken into account
$e^+e^- \to \omega\eta$ is excluded

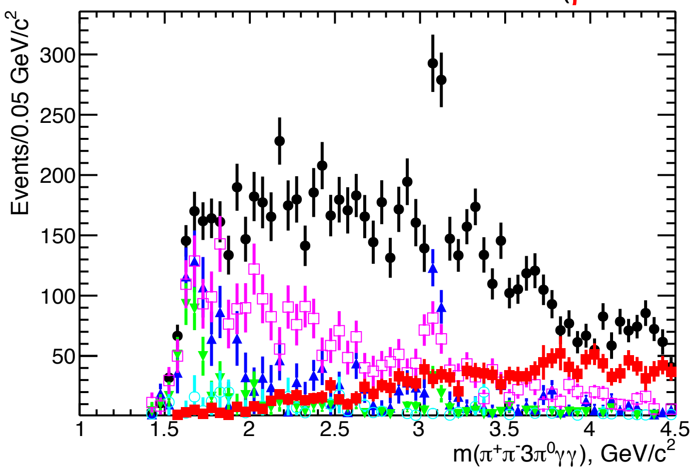
No other measurements

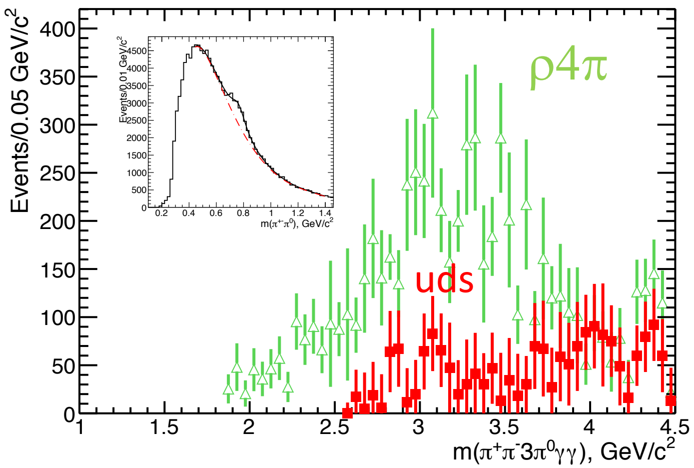
Good agreement with previously measured cross sections in different decay modes of ω, η

Contribution from different channels



Contribution from selected intermediate states ($\rho 4\pi$ is not shown)





The observed $2\pi 4\pi^0$ events are covered by the $\pi^+\pi^-\pi^0\eta(\omega\eta)$, $\omega 3\pi^0$, $\rho\pi 3\pi^0$ for < ~2.9 GeV, and probably some contribution from $\rho^+\rho^- 2\pi^0$ channels for 2.9-4.0 GeV

J/ψ region for $\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\pi^0$ and $\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0$

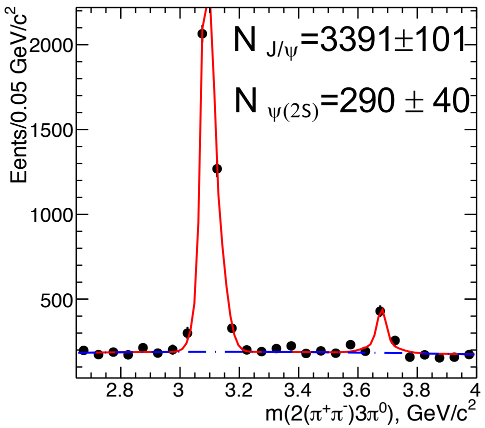


TABLE VIII: Summary of the J/ψ and $\psi(2S)$ branching fractions.

Measured Quantity	Measured Value (eV)	J/ψ or $\psi(2S)$ Branching Fraction (10^{-3}) Calculated, this work	PDG [28]
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\pi^0}$	345.0±10.0±50.0	62.0±2.0±9.0	no entry
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\omega\pi^+\pi^-\pi^0\pi^0}\cdot\mathcal{B}_{\omega\to\pi^+\pi^-\pi^0}$	165.0±9.0 ±25.0	33.0±2.0±5.0	no entry
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\eta\pi^+\pi^-\pi^0\pi^0}\cdot\mathcal{B}_{\eta\to\pi^+\pi^-\pi^0}$	6.0±4.0 ±1.0	4.8±3.2±0.8	2.3 ±0.5
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\pi^+\pi^-\pi^+\pi^-\eta}\cdot\mathcal{B}_{\eta\to\pi^0\pi^0\pi^0}$	5.6±2.6 ±0.8	2.6±1.2±0.5	2.26±0.28
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\rho^\pm\pi^\mp\pi^+\pi^-\pi^0\pi^0}$	155.0±26.0±36.0	28.0±4.7±6.6	no entry
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\rho^+\rho^-\pi^+\pi^-\pi^0}$	32.0±13.0±15.0	5.7±2.4±2.7	no entry
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\eta}\cdot\mathcal{B}_{\eta\to\gamma\gamma}$	9.1±2.6 ±1.4	4.2±1.2±0.6	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\pi^0}$	33.0±5.0 ±5.0	14.0±2.0±2.0	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to J/\psi\pi^0\pi^0}\cdot\mathcal{B}_{J/\psi\to\pi^+\pi^-\pi^+\pi^-\pi^0}$	14.8±2.6 ±2.2	34.7±6.1±5.2	33.7 ±2.6
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to J/\psi\pi^+\pi^-}\cdot\mathcal{B}_{J/\psi\to\pi^+\pi^-\pi^0\pi^0\pi^0}$	19.2±4.5 ±3.2	23.8±5.6±3.6	27.1 ±2.9
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\omega\pi^+\pi^-\pi^0\pi^0}\cdot\mathcal{B}_{\omega\to\pi^+\pi^-\pi^0}$	18.0±4.0 ±3.0	8.7±1.9±1.5	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0\eta}\cdot\mathcal{B}_{\eta\to\gamma\gamma}$	<1. 9 at 90% C.L.	<2. 0 at 90% C.L.	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\pi^+\pi^-\pi^+\pi^-\eta}\cdot\mathcal{B}_{\eta\to\pi^0\pi^0\pi^0}$	<2. 3 at 90% C.L.	<2. 4 at 90% C.L.	1.2 ±0.6

The largest decay mode of J/ψ !!

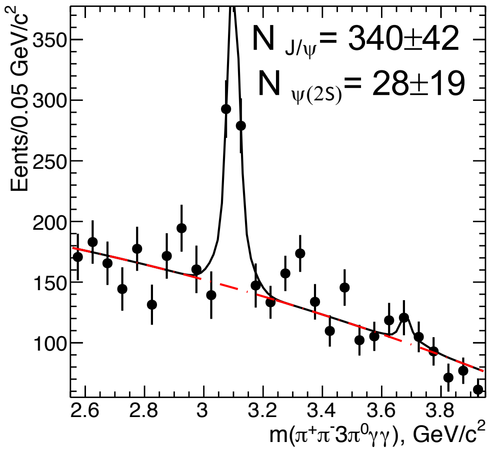


TABLE VII: Summary of the J/ψ and $\psi(2S)$ branching fractions.

Measured Quantity	Measured Value (eV)	J/ψ or $\psi(2S)$ Branching Fraction (10^{-3}) Calculated, this work	PDG [28]
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0}$	35.8±4.4±5.4	6.5±0.8±1.0	no entry
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\eta\pi^+\pi^-\pi^0}\cdot\mathcal{B}_{\eta\to\pi^0\pi^0\pi^0}$	21.1±1.7±3.2	11.9±0.9±2.3	no entry
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\omega\eta}\cdot\mathcal{B}_{\omega\to\pi^+\pi^-\pi^0}\cdot\mathcal{B}_{\eta\to\pi^0\pi^0\pi^0}$	4.9±2.1±0.7	3.0±1.3±0.5	1.74±0.20
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\omega\pi^0\pi^0\pi^0}\cdot\mathcal{B}_{\omega\to\pi^+\pi^-\pi^0}$	9.4±2.3±1.5	1.9±0.5±0.3	no entry
$\Gamma^{J/\psi}_{ee}\cdot\mathcal{B}_{J/\psi\to\pi^+\pi^-\pi^0\pi^0\pi^0\eta}\cdot\mathcal{B}_{\eta\to\gamma\gamma}$	10.6±1.6±1.6	4.9±0.8±0.8	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0}$	3.3±2.3±0.5	1.4±1.0±0.2	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\eta\pi^+\pi^-\pi^0}\cdot\mathcal{B}_{\eta\to\pi^0\pi^0\pi^0}$	<3. 0 at 90% C.L.	<3. 5 at 90% C.L.	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\omega\eta}\cdot\mathcal{B}_{\omega\to\pi^+\pi^-\pi^0}\cdot\mathcal{B}_{\eta\to\pi^0\pi^0\pi^0}$	<1. 1 at 90% C.L.	<1. 4 at 90% C.L.	<0. 11 at 90% C.L.
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\omega\pi^0\pi^0\pi^0}\cdot\mathcal{B}_{\omega\to\pi^+\pi^-\pi^0}$	<1. 6 at 90% C.L.	<0. 8 at 90% C.L.	no entry
$\Gamma^{\psi(2S)}_{ee}\cdot\mathcal{B}_{\psi(2S)\to\pi^+\pi^-\pi^0\pi^0\pi^0\eta}\cdot\mathcal{B}_{\eta\to\gamma\gamma}$	<1. 9 at 90% C.L.	<2. 0 at 90% C.L.	no entry

New BaBar $e^+e^- \to \pi^+\pi^-\pi^0$

The process $e^+e^- \to \pi^+\pi^-\pi^0$ gives the second largest contribution into $a_\mu^{had,LO-VP}$ and its error.

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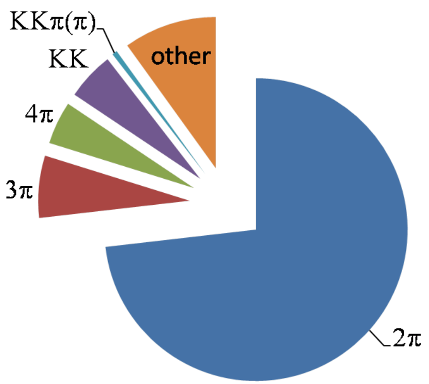
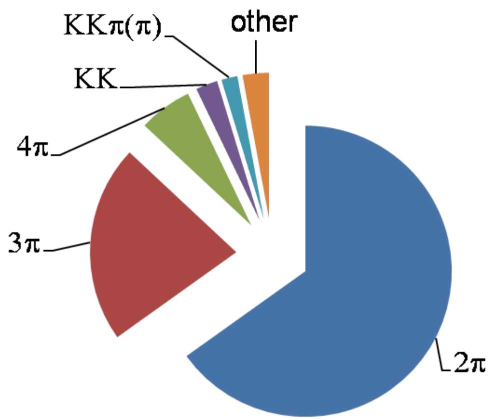
$a_\mu^{had,LO-VP}$

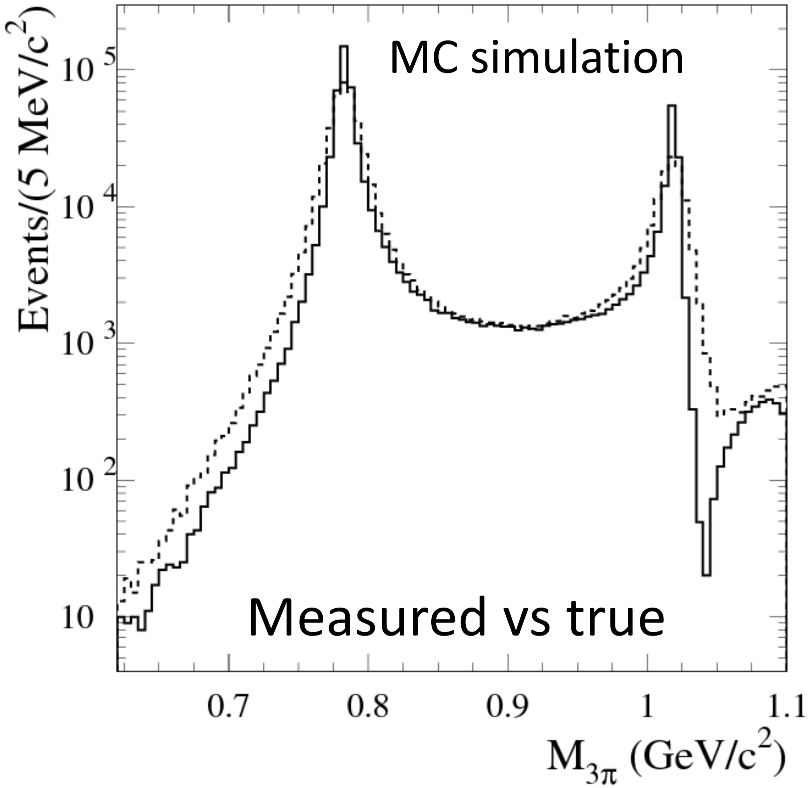


$a_\mu^{had,LO-VP}$ error squared



- ✓ Previous BABAR measurement was based on 1/5 of the existing data set. The $e^+e^- \to \pi^+\pi^-\pi^0$ cross section was measured in the range 1.05-3 GeV – no XS below 1.05 GeV
- ✓ In the new analysis we measure the cross section also below 1.05 GeV, in the region of the ρ, ω, and ϕ resonances.
- ✓ Currently the $e^+e^- \to \pi^+\pi^-\pi^0$ contribution to $a_\mu^{had,LO-VP}$ is known with about 3% accuracy We plan to improve this accuracy to about 1.5%. Preliminary results ready for EPS2021(?)

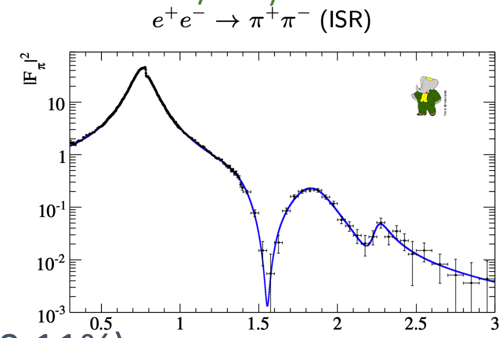
$\pi^+\pi^-\pi^0$ mass spectrum below 1.1 GeV



- The mass spectrum varies by 5 orders of magnitude and has narrow peaks. The result of unfolding strongly depends on quality of resolution simulation.
- To study data-MC difference in resolution, we fit to the observed mass spectrum with the VMD model.
- The widths of ω and ϕ resonances are measured with high accuracy. From the fit we determine parameters of the (narrow) Gaussian smearing function.
- The long tails of the mass resolution function depend on requirement on χ^2 of the kinematic fit used for event selection. To understand quality of the tail simulation, we compare results of the VMD fit for spectra obtained with different cuts on χ^2.

New BABAR ISR $\mu\mu\gamma$ / $\pi\pi\gamma$ / KKγ analysis

Published analysis : PRL 2009 ($\pi\pi/\mu\mu$) + PR 2012 ($\pi\pi/\mu\mu$) + PR 2014 (K+K-) + PR 2014 (interference ISR/FSR)



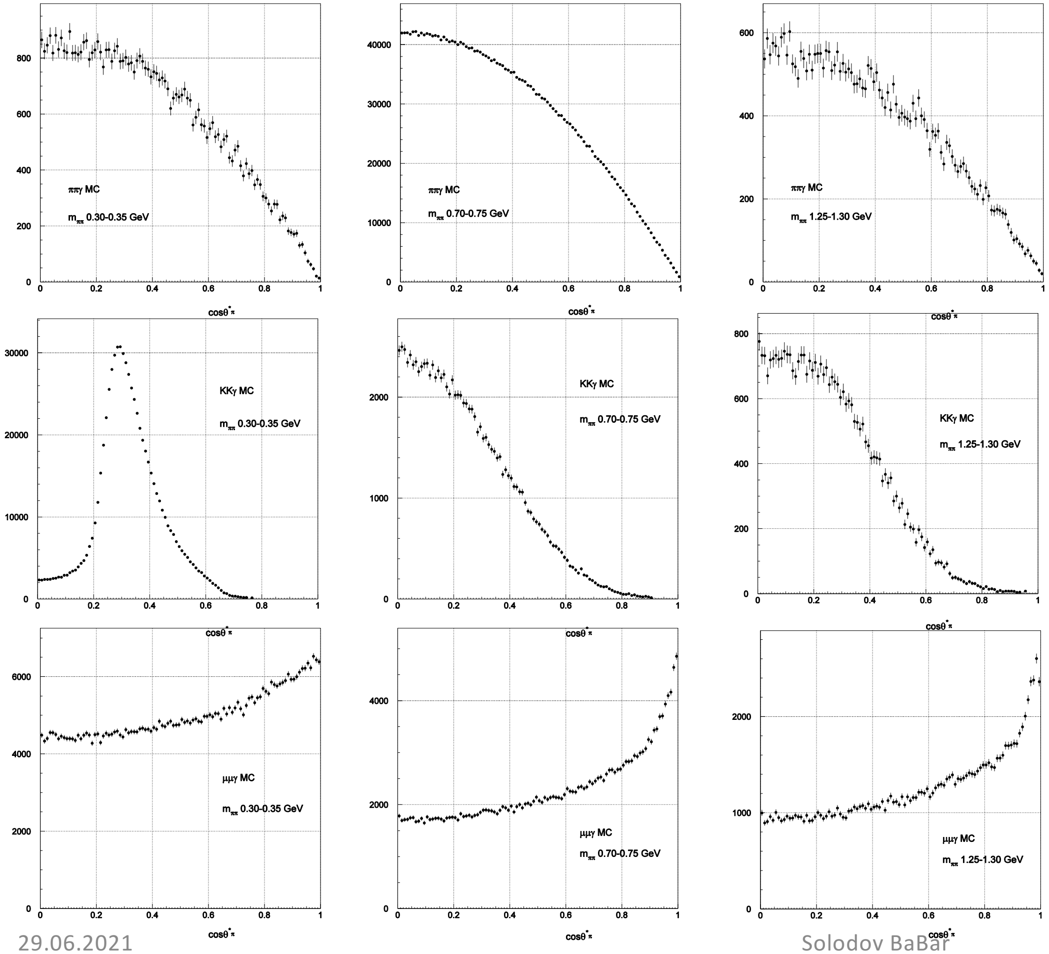
- PID used to separate $\pi\pi\gamma$ and $\mu\mu\gamma$ channels
- P>1 GeV to ensure reliable μ ID
- NLO kinematic fits (2 charged tracks + main ISR γ + add ISR or FSR γ
- Runs 1-4 (half statistics)
- Trigger, tracking, PID efficiencies obtained by the tag&probe method
- For $\pi\pi\gamma/\mu\mu\gamma$ ratio: PID systematic uncertainty dominant (0.44%), tracking (0.11%)
- NLO kinematic fits with loose χ^2 cuts to ensure low inefficiency

New analysis in progress $\to$ 2022

- $\pi\pi\gamma$, KKγ, and $\mu\mu\gamma$ samples separated by fitting the angular distribution in in the 2-particle CM: essential to keep low-momentum tracks
- Trigger and tracking efficiency method needs to be extended for tracks well below 1 GeV
- In practice tracks are reconstructed in BABAR down to $p_T \sim 0.1$ GeV/c
- Runs 1-6 (full data + no PID $\Rightarrow$ statistics $\times 7$ and smaller systematic uncertainty, **blind**
- Improved NLO kinematic fits + NNLO fits for checks
- Mass range limited to ~1.4 GeV (>99% of $\pi\pi$ contribution to a_μ)

MC angular distributions ($|\cos\theta^*_\pi|$)

$m_{\pi\pi}$ (GeV) 0.30-0.35 0.70-0.75 1.25-1.30

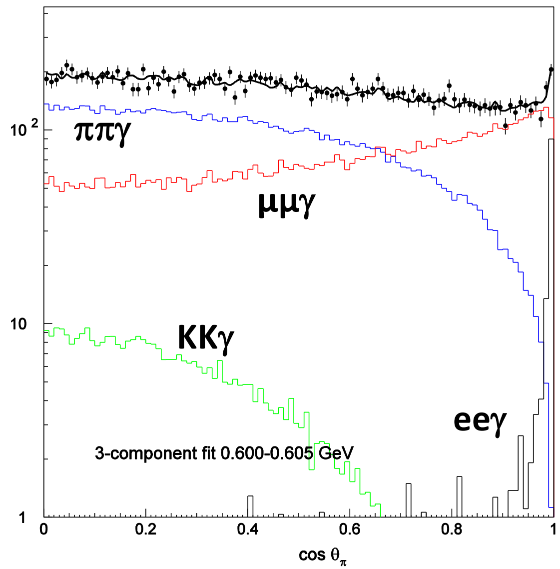


$\pi\pi\gamma$

KKγ

μμγ

preliminary fits (test sample)



New: $2K3\pi$

Below 2 GeV, probably, (last?) final state with sizable XS, which is included(?) via iso-spin relations, is $e^+e^-\to K\underline{K}3\pi$

What we know:

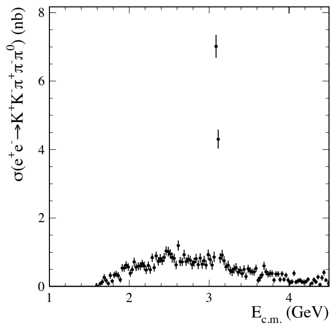
1. $e^+e^-\to K^+K^-\pi^+\pi^-\pi^0$ - the only measured XS – BaBar **Phys.Rev. D76 (2007) 092005**

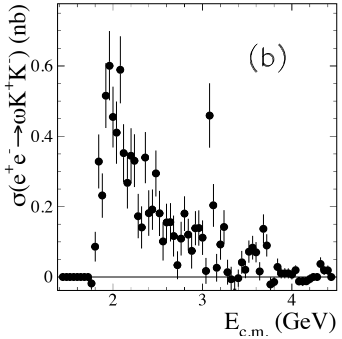
2. $e^+e^-\to K^+K^-\pi^0\pi^0\pi^0$ - No info . Partly from $\phi\eta$

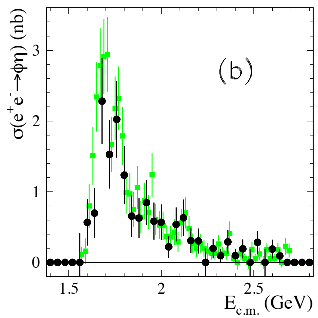
3. $e^+e^-\to K_SK_L\pi^0\pi^0\pi^0$ - No info . Partly from $\phi\eta$
   $e^+e^-\to K_SK_L\pi^+\pi^-\pi^0$
   $e^+e^-\to K_SK_S\pi^+\pi^-\pi^0$

4. $e^+e^-\to K^{+-}K_{S,L}\pi^{-+}\pi^0\pi^0$ - No info

5. $e^+e^-\to K^{+-}K_{S,L}\pi^{-+}\pi^+\pi^-$ - No info







Analysis is in progress

Conclusion

- BaBar is continuing to present data for the low energy e^+e^- cross sections
- Results for two new analyses of multi-hadron processes are presented
- Most important for g-2 analyses ($e^+e^- \to \pi^+\pi^-$, $\pi^+\pi^-\pi^0$) are revisiting using full data set
- If no ideas, these two and $2K3\pi$ studies will move this BaBar program to the end (?)

Thank you